

**Inventory and Preliminary Habitat Relationships
of Forest Songbirds and Other Vertebrates in the
Tofino Creek Watershed, Vancouver Island,
British Columbia**

2000

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E. Todd Manning



Ministry of Forests Research Program

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Prepared by

E. Todd Manning

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712 Yates Street

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ABSTRACT

A research project was conducted in the Tofino Creek watershed on western Vancouver Island, British Columbia, during the spring and summer of 1992. The major objectives of this study were to determine the presence of birds, mammals, and amphibians found in different coastal western hemlock (*Tsuga heterophylla*) and mountain hemlock (*T. mertensiana*) habitats in the watershed, and to compare the relative abundance of forest birds living in these habitats. Specific surveys were conducted for forest breeding birds, salamanders, small mammals, owls, and Marbled Murrelets (*Brachyramphus marmoratus*).

Fifty-two species of birds were detected in eight habitat types throughout the valley between May and July 1992. Eight species of mammals and four species of amphibians were also detected during this period. The relative abundance of forest birds differed significantly ($p < 0.05$) between some habitat types found in the watershed.

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1 INTRODUCTION

The overall strategy goal for the Tofino Creek drainage as defined in the Tofino Creek Integrated Resource Management Strategy (B.C. Ministry of Forests 1991) is "to plan for the recognition and management of present and future values in . . . a manner which ensures their compatability and sustainability." Such a strategy of adaptive management recognizes both timber and non-timber resources and the use of appropriate silviculture systems. Recognition of specific resource value objectives includes the consideration of ecological processes, timber, wildlife, fisheries, landscape, recreation, soils, water, minerals, and employment. The following planning objectives were cited by the Ecological Values Subcommittee Report for Tofino Creek (B.C. Ministry of Forests 1991):

- 1) to identify and sustain the natural biological diversity of representative plant and animal ecosystem associations through application of appropriate protection measures; and
- 2) to inventory and assess wildlife habitat suitability and capability and develop short-term and long-term management prescriptions.

The relative abundance of vertebrate species in unmerchantable or inoperable timber types compared to merchantable old-growth valley-bottom stands in the Coastal Western Hemlock (CWH) biogeoclimatic zone is poorly understood (D. Seip, B.C. Ministry of Forests, Vancouver Forest Region, pers. comm., 1992). Tofino Creek, with its high proportion of unmerchantable and inoperable area (48%), mature and old-growth stands, and riparian streamside zones, afforded an excellent comparative context for inventorying vertebrate populations and their requisite habitats.

The research objectives of this project were:

- 1) to determine the presence/absence of major vertebrate fauna (mammals, birds, and amphibians) living in different habitats within the Tofino Creek watershed; and
- 2) to compare the relative abundance of forest breeding birds living in different habitat types within the Tofino Creek watershed.

2 STUDY AREA

The Tofino Creek watershed encompasses approximately 5100 ha (Table 1) at the head of Tofino Inlet in the Alberni-Clayoquot Region on the west coast of Vancouver Island (Figure 1). Tofino Creek is characterized as a typical north-temperate coastal valley. The climate is cool mesothermal with cool summers and mild winters (8.9° C mean annual temperature). Annual mean rainfall (approximately 3200 mm) is abundant with periodic high storm discharges (B.C. Ministry of Forests 1991). The valley lies in a general north-east-southwest orientation and consists of a valley-bottom floodplain surrounded by steep slopes with coniferous forests and exposed granite bedrock walls. Elevations range from sea level to 1500 m. Soils are most often ferro-humic podzols, characterized by the gradual build-up of organic matter at the ground surface (B.C. Ministry of Forests 1991). Soil nutrient and moisture regimes are variable and are often microsite-dependent. Generally, soils may be classified as poor-to-medium and fresh-to-moist (Inselberg 1993).

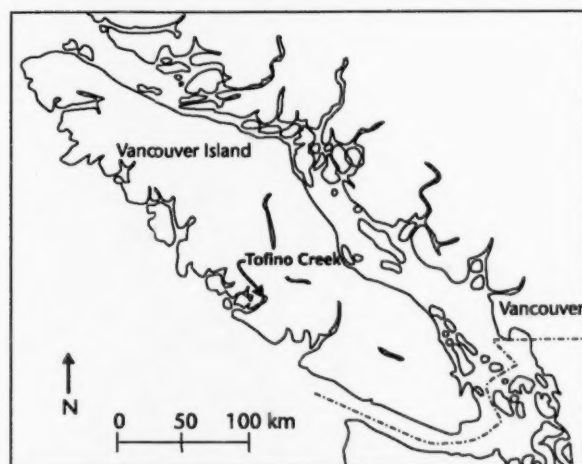


FIGURE 1 Location of the Tofino Creek study area on Vancouver Island

Tofino Creek lies within the Coastal Western Hemlock (CWH) and Mountain Hemlock (MH) biogeoclimatic zones. One of the two biogeoclimatic subzones of the CWH in the watershed, has two variants (Table 1). The MH has two subzones represented within the drainage, each with one variant. Additional descriptions of these biogeoclimatic units may be found in Pojar et al. 1987.

Zonal site associations for the biogeoclimatic units within the Tofino Creek watershed are summarized in Table 2.

The CWH is the most productive forest region in Canada (Pojar et al. 1991). Western hemlock, western redcedar, amabilis fir, Sitka spruce, yellow-cedar, and mountain hemlock are the major coniferous tree species found in the watershed (see Appendix 1 for scientific names of floral species). Red alder and black cottonwood are the dominant hardwoods found in disturbed and riparian areas, primarily in the valley bottom and along the Deer Bay estuary. Thirty-nine percent (1982 ha) of the landbase in Tofino Creek,

TABLE 1 Elevational ranges and areas of biogeoclimatic units in the Tofino Creek watershed, Vancouver Island

Zone	Subzone	Variant	Abbrev.	Elevation(m)	Approx. area (ha) (%)
Coastal Western Hemlock (CWH)	Very Wet Hypermaritime (vh)	Southern (1)	CWHvh1	0-150	150 (3)
Coastal Western Hemlock	Very Wet Maritime (vm)	Submontane (1)	CWHvm1	150-500	1810 (36)
Coastal Western Hemlock	Very Wet Maritime (vm)	Montane (2)	CWHvm2	500-950	2000 (39)
Mountain Hemlock* (MH)			MH	950-1500	1140 (22)
Total					5100 (100)

* The sampling unit in this study was the lower-elevation Windward Moist Maritime MH variant (MHmm1). The MH zone in the Tofino Creek watershed also includes the higher-elevation Windward Parkland Moist Maritime MH variant. A small area of the Alpine Tundra zone is also present at the summits of mountains in the watershed. The area of the AT has been included with the MH in this table.

TABLE 2 Zonal site associations of the Tofino Creek watershed, Vancouver Island

Biogeoclimatic subzone	Zonal site association*
CWHvh	CwYc† – salal
CWHvm	HwBa – blueberry
MHmm	HmBa – blueberry

* Each site association represents a group of ecologically similar sites that are characterized by a certain old-seral vegetation and a certain range of climates. A more thorough description of zonal site associations for the Tofino Creek watershed is found in Inselberg (1993).

† Tree species codes: Cw = western redcedar; Yc = yellow-cedar; Hw = western hemlock; Ba = amabilis fir; Hm = mountain hemlock.

including 260 ha logged in the 1980s, is classified as operable working forest (B.C. Ministry of Forests 1991). Forty-eight percent (2434 ha) is rated as inoperable or unmerchantable due to inaccessibility, unstable ground, low site index, or non-productivity. The remaining 13% (684 ha) is classified as recreational, including scenic Virgin Falls, fisheries sensitive areas (14 ha), and old-growth experiential (6 ha).

3 METHODS

3.1 Forest Bird Point Count Census Technique

Forest breeding bird surveys were conducted during early May, June, and July 1992 using the fixed-radius point count census technique. The advantages and limitations of this technique have been described in detail by Resources Inventory Committee (RIC) 1998a, Bryant (1997), Manuwal and Carey (1991), and Verner (1985). Its major limitations are: 1) potential difficulties associated with observer ability and consistency in placing bird detections within the census point radius; 2) under-representation of rare species; and 3) meeting the implicit assumptions that all birds within the boundaries of the fixed-radius are detected, that individuals are not counted more than once, that birds outside the radius are not counted, and that birds do not move into or out of the radius in response to the observer. Nevertheless, this method was chosen because of its overall efficiency of use, the ability to survey birds over a large area, and the ability to provide information on presence/absence and relative abundance of bird species across different habitat types. Point counts have been used successfully by numerous researchers to survey both breeding and wintering birds and mammals (Robbins 1978; Reynolds et al. 1980; Wetmore et al. 1985; Eckert and Savard 1991; Bryant et al. 1993; Bryant 1994, 1995, 1997). However, point counts are generally unsuitable for certain groups of birds such as seabirds, shorebirds, diurnal raptors, and owls (Bryant et al. 1993).

All birds seen or heard within 75 m of the point centre during a 12-minute period were recorded. This period was divided into three, 4-minute intervals for ease of recording. The horizontal distance and bearing to each bird was estimated and its position was then plotted on a standard data form showing concentric radii up to 75 m from the point centre (Appendix 2). Because of the difficulty of precisely estimating location distances greater than 50 m (especially in closed forest habitats), detections that occurred between 50 and 75 m from the point centre were not differentiated, but were coded and analyzed for species occurrence and detection distance as "60 m." Detections at distances greater than 75 m were not recorded. This technique provided an

estimate of the relative abundance of each bird species (i.e., mean number of detections per point or per habitat type). Bird behaviour (song, call, flight within plot, etc.) for each observation was also noted. Birds flying over or through the census plot were not recorded.

All censuses were conducted between 0500 and 1000 hours. Each census point in the CWHvm1 and CWHvm2 habitats was visited three times during the breeding season (early May, June, and July 1992). Because of access and poor weather conditions, only two replicate breeding bird surveys (early June and July 1992) were conducted in the MHmm1 variant. The average linear distance between successive point centres was 150 m. Other researchers have used point centre separation distances of 200 m (Eckert and Savard 1991) in similar studies of forest bird communities. However, the highly variable, steep topography and dense forest cover of Tofino Creek necessitated smaller point centre separation distances. Line transects between census points were walked using a compass and thread-chain odometer in order to maintain bearing and measure distance. Where topography and access conditions were not limiting, census points were surveyed in reverse order on successive replicates to reduce potential time-of-day-related sampling bias.

Eighty-one breeding bird census points, representing eight habitat types, were established in the CWHvh1 (southern), CWHvm1 (submontane), CWHvm2 (montane), and MHmm1 (windward) biogeoclimatic variants. These were defined by actual soil moisture regime (for mature and old coniferous forest types), by seral stage (for clearcuts or hardwood stands), or by variant (for CWHvm2 and MHmm1), and are summarized in Table 3. Point centres, except for clearcut plots, were located at least 75 m from any road or cutblock boundary to reduce potential edge effects, thereby facilitating sampling under interior forest conditions.

3.1.1 Description of forest bird census points All forest bird census points were map-located then ground truthed and plotted on 1:20 000-scale forest cover maps. Each point centre was identified in the field by a bright yellow plastic sign (15 × 15 cm square) nailed to a tree at eye level. These signs contained information describing plot number, subzone and variant, and soil nutrient and moisture regimes. Flagging tape was also used to mark and

TABLE 3 Number of forest breeding bird census point locations by habitat type, Tofino Creek, Vancouver Island, 1992

Dry / slightly dry	Fresh	Moist / very moist		Hard- wood	Clear- cut			TOTAL
		CWH vm1	CWH vm1			CWH vh1/vm1	CWH vm2	
14	21	12	2	5	9	10	8	81

* Variation in sample size by habitat type occurred because of difficulties in locating census points based on actual soil moisture regime (ASMR), plus the need to spatially separate these points by 150 m. Soil moisture regime at nine wet/floodplain census points (50–54, 60–61, 66–67) was quite variable. Only two points (66–67) clearly indicated a wet ASMR at the time of sampling, while the other seven points were described as fresh overall. This resulted in a higher number of fresh, and a lower number of wet, census points in the total sample.

† The limited extent of hardwood forest in the watershed resulted in a low number of census points for this habitat type.

‡ Clearcut ages ranged from 3 to 5 years.

locate census points. Usually, eight to ten census points were laid out in a broad, inverted U-shaped pattern. At each census point a variety of descriptive information was recorded. This included biogeoclimatic subzone and variant, soil nutrient regime (SNR), actual soil moisture regime (ASMR), slope (%), aspect (°), elevation (m), and canopy crown closure (%). SNR was defined according to general nutritional status for plant growth (p = poor; m = medium; r = rich), while ASMR was assessed using the classification system described by Klinka et al. (1984), which ranges from very dry to very wet.¹ Slope and aspect were measured with a clinometer and a compass, respectively. Compass readings were corrected for declination. Elevation was measured at census point centres with an altimeter, which was calibrated at sea level daily. Canopy crown closure was estimated by extending a vertical projection of the outline of the main tree canopy crown onto the ground surface. This value represented an average for the main tree stratum across the census plot to a radius of 50 m. Dominant understory vegetation was described and, where a reasonable estimate could be made, vegetative ground cover (%) was recorded using the vertical projection technique.² A summary of the above data for all points is provided in Appendix 3.

3.2 Marbled Murrelet Survey

Ten murrelet census stations were spaced along the Tofino Creek mainline road, ranging from sea level at the Deer Bay estuary to 350 m elevation approximately 5 km up the valley (Figure 2; stations labelled as "Owl 1-10"). Along this gradient, four habitat types were represented (Table 4).

Spacing between census stations was usually 500 m, but varied slightly between some stations because of the patchiness of habitats along the valley corridor. Roads were chosen to survey murrelets because of the steep and often inaccessible terrain in Tofino Creek, and because visibility and auditory detection of murrelets flying overhead or circling would be enhanced. Standardized murrelet data collection forms and observation protocol developed by the Canadian Wildlife Service and later by the Resources Inventory Committee (RIC 1997a) were used to record information such as number of "keer" calls, number of birds seen, height relative to canopy, flight direction, behaviour, and closest distance.

TABLE 4 *Habitat types represented at murrelet/owl survey stations, Tofino Creek, Vancouver Island, 1992*

Habitat type	Station number(s)
Old-growth forest (census station surrounded on all sides by old-growth forest, generally more than 250 years old)	5, 3, 1
Coniferous forest edge (census station bordered on at least one side by a natural or human-made opening)	10, 7, 2
Clearcut (3-5 years since harvesting)	9, 8, 6
Hardwood (along Deer Bay estuary)	4

1 vd = very dry; md = moderately dry; sd = slightly dry; d = dry; f = fresh; m = moist; vm = very moist; w = wet; vw = very wet.

2 More detailed information on site description methodology can be found in Luttmerding et al. (1990).

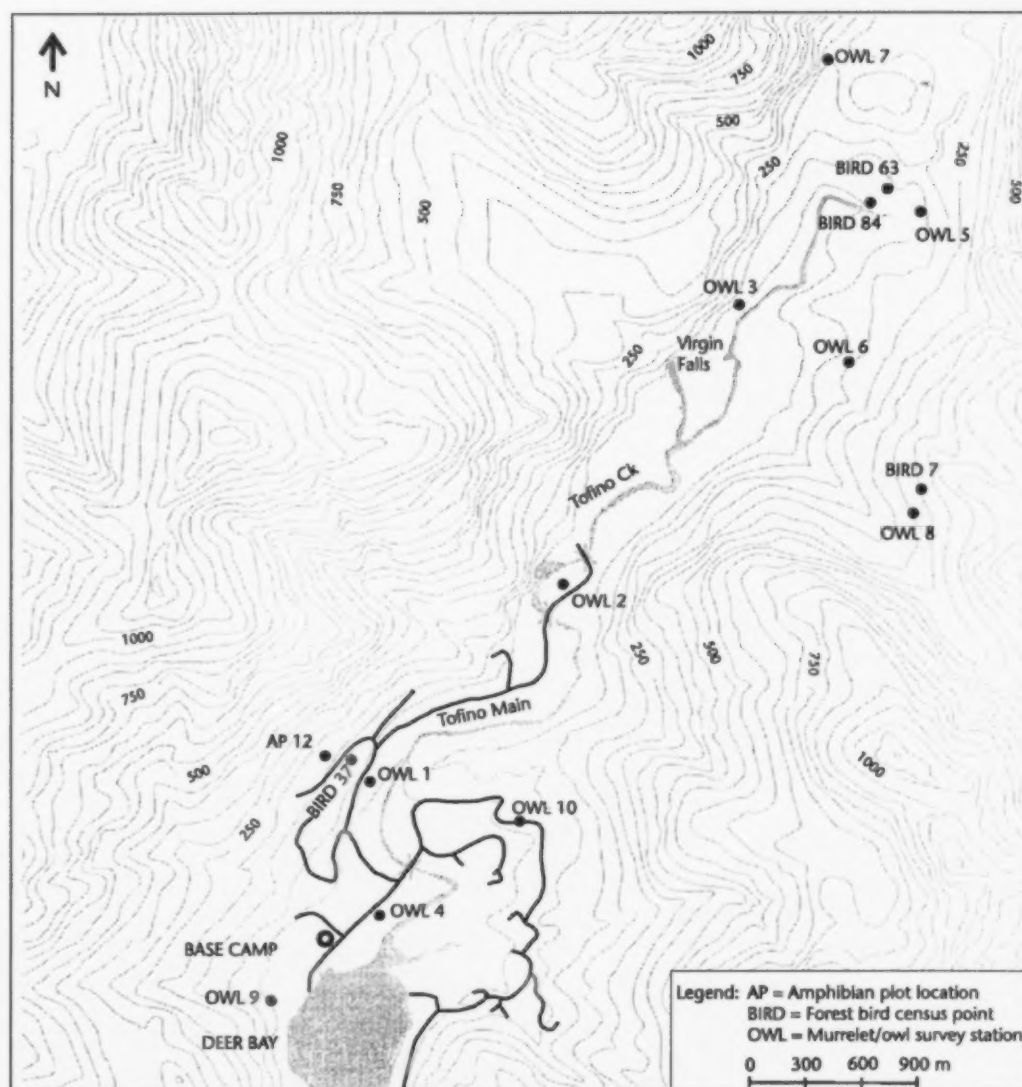


FIGURE 2 Locations of plots, census points, and survey stations in the Tofino Creek study area.

A 10-minute census was conducted on two successive days (July 6–7, 1992) at each of the 10 stations. Stations were surveyed in reverse order on the second day to reduce potential sampling bias related to the time of day. All censuses began 1 hour before official sunrise (0515 hours) and continued for 1 hour after sunrise. Censusing on the third day (July 8, 1992) involved only one of the survey stations. A continuous 2-hour survey was conducted at the station with the most murrelet observations from the previous 2 days (old-growth station 5; see Figure 2).

3.3 Owl Searches

Limited searches for owls, including Barred Owl, Western Screech Owl, Northern Saw-whet Owl, and Northern Pygmy-Owl, were conducted after dusk from early May to mid-July 1992. Tape-recorded vocalizations played

back over a small portable stereo were used to attract and detect owls. This technique has been used successfully to provide qualitative data on species presence or absence (RIC 1997b; Shepard and Manning 1997; D. Fraser, Arenaria Research, Victoria, pers. comm., 1992). However, information on species abundance and distribution can generally not be obtained in this manner due to the variability of owl responses and the inability of the observer to determine how far a responding bird may have travelled, and from where (e.g., birds can travel from distant stand types, or may respond to playbacks but fly in undetected).

Playbacks were conducted along roads during the late evening between 2200 and 0100 hours using the 10 census stations used for the Marbled Murrelet survey (Table 4). Each census station was surveyed three times. Owl vocalizations were played back for 15 minutes at each station.

3.4 Amphibian Searches

Twenty-eight time-restricted searches for salamanders (RIC 1999) were conducted during the first 2 weeks of May 1992. Rocks and decaying logs were manually overturned, then replaced, and the loose bark of stumps or fallen logs was carefully pulled back to expose resting salamanders. Search effort was limited to an area of 1 hectare by two people for a period of 1 hour. Four searches were conducted in each of the six CWHvm1 habitat types and the CWHvm2 variant. An additional 1-hour search was conducted in each of four moist/very moist Hw/Ba old-growth stands in early July 1992. These were situated in low (near breeding bird plot 37), mid (near amphibian plot 12), and upper (1.5 km northeast of owl station 7 along Tofino Creek) valley positions (Figure 2). No searches were conducted in the MHmm1. The number of animals of each species captured per search period was used to provide an index of relative salamander abundance.

3.5 Small Mammal Survey

A limited small mammal trapping program was conducted for 6 days in early June and 14 days in early July 1992. Five pitfall traps and three Sherman traps were installed at each of nine trap sites representing five habitat types in the lower valley (RIC 1998b). Trap site locations were established in the CWHvm1 variant according to ASMR (i.e., dry/slightly dry, fresh, wet/floodplain), and also in the hardwood and clearcut habitat types.

Pitfall traps were submerged in the ground to a depth of approximately 40 cm, and were arranged in a spoke pattern with one trap at the centre and four traps radiating outward. The distance from the centre trap to outlying traps was approximately 2 m. Small branches, logs, and other vegetation and debris were used to create natural-looking barriers and travel paths, directing animals toward the pitfalls. Sherman traps were placed nearby, and were pre-baited with peanut butter and oatmeal flakes for 3 days prior to trap activation.

3.6 Incidental Observation

Observations of various animals were made while conducting other survey work in the valley. These data included direct observation (e.g., visual sightings and vocalizations), and presence of animal sign (e.g., scats, pellet groups, tracks or trails, scent and sign marking, feeding sign, burrows, dens, and nests or nest cavities).

3.7 Data Compilation and Analysis

Because of small sample sizes and the desired level of inventory intensity (i.e., collection of presence/absence information only), survey data for Marbled Murrelets, owls, amphibians, and small mammals were recorded as frequencies (counts) and were analyzed with simple descriptive statistics.

3.7.1 Forest birds Forest breeding bird detections were compiled as mean number of detections per census point for each habitat type. Averaging the number of each species recorded during replicate surveys can reduce survey bias introduced by migrant "waves" (e.g., Orange-crowned Warbler), but will often under-estimate species with low detectability (e.g., woodpeckers) and late migrants such as Swainson's Thrush, which are rarely encountered during the first surveys of the breeding season (Bryant et al. 1993; Bryant 1994).

All observations within the fixed-radius plot during a given census interval, including territorial songs, non-territorial calls, and other observations, were recorded and pooled in the data analysis. Thus, singing males as well as females and juveniles were included in the point counts. Pooling was used to reduce biases associated with classifying "song" versus "call." Examples of bird species in the watershed that have indistinguishable songs and calls or that do not sing are Chestnut-backed Chickadee, Golden-crowned Kinglet, Red-breasted Nuthatch, Vaux's Swift, swallows, woodpeckers, crows, and ravens. Raphael (1987) showed that total detections adequately reflect the relative abundance of most forest birds.

For all bird species (pooled) a nonparametric Friedman rank order test (Siegel 1956), using the three censuses (May–July) as repeated measures, was used to provide an initial comparison of mean bird detections by habitat type. (Note: the Mountain Hemlock variant was excluded since no censuses were conducted there in May.) A Kendall's coefficient of correlation (Siegel 1956) was calculated to measure the concordance of the three repeated measures.

One-way repeated measures analysis of variance (ANOVA) was then used to test for differences in mean bird abundance among all habitat types for the last two censuses (June–July). In the ANOVA, bird census points were considered to be the experimental units that were repeatedly measured; census points were grouped by the habitat type in which they occurred. A Bartlett test was applied to check for homogeneity of variances in mean bird detections. Where necessary these data were log transformed in order to meet the assumption of homoscedasticity (Zar 1974). Where significant differences in mean abundance occurred, a post-analysis multiple means test (i.e., nonparametric Tukey HSD) (Zar 1974) was conducted to reveal the association of the habitats. The pairwise comparisons were summarized by ordering the habitats from low to high and underlining the homogeneous groups. Finally, a set of orthogonal comparisons or contrasts using repeated measures ANOVA was applied to the homogeneous habitat groups in order to determine which habitats were different from one another. The following contrasts were constructed:

1. CWHvm2 versus CWHvh1/vm1 forested (d/sd+f+m/vm+wet+hardwood)
2. Clearcut versus CWHvh1/vm1 forested (d/sd+f+m/vm+wet+hardwood)
3. Hardwood versus CWHvm1 coniferous (d/sd+f+m/vm+wet)
4. Dry coniferous (d/sd) versus moist coniferous (f+m/vm+wet)
5. Wet coniferous versus moderate coniferous (f+m/vm)

Mean number of warbler and woodpecker detections by habitat type were also analyzed separately. Because of the small sample sizes for these two guilds, the data proved too sparse (i.e., many of the census points did not observe warblers or woodpeckers) to conduct ANOVA. Consequently, a Friedman test was conducted to determine any differences in relative abundance. (Note: the MHmm1 habitat was omitted from this analysis because of the absence of data collection in the first census period).

Forest bird detection means and standard errors for the eight habitat types

were calculated from the census point means. All error bars illustrated in the analyses are ± 1 standard error (SE). All statistical tests were conducted at the 0.05 level of significance.

4 RESULTS

4.1 Forest Spring Breeding Bird Survey

A total of 2521 observations of 52 species of birds was recorded during the survey period between May and July 1992. Of these, 1791 (71%) were songs, 553 (22%) were calls, and the remaining 177 (7%) included visual flights within the census plot area, territorial behaviour such as drumming and calling from the nest, and direct visual observation of activity within the plot.

Sixty-two percent (1565) of all bird observations occurred between 26 and 50 m from the observer, 26% (654) occurred between 50 and 75 m, and 12% (302) were closer than 26 m. Two bird species are on the provincial Blue (vulnerable) status list (Wildlife Branch 1998): Hutton's Vireo and Northern Pygmy-Owl. One species, the Marbled Murrelet, is on the provincial Red (considered for designation as endangered or threatened) status list (Wildlife Branch 1998). A complete list of all bird species observed, including incidental observations, is found in Appendix 4.

Average main tree canopy height and crown closure for the CWHvm1 coniferous census points was 43 m and 51%. The CWHvm2 and MHmm1 census points were 28 m and 30%, and 20 m and 26%, respectively.

4.1.1 Bird detections by habitat type Mean number of bird detections by species per census point in the eight habitat types at Tofino Creek is summarized in Table 5. Mean number of bird detections (for all birds pooled) by habitat type is illustrated in Figure 3 and summarized in Appendix 5.

Friedman's test (without the MHmm1 habitat) indicated that there was a significant difference in mean number of bird detections among all other habitats ($p=0.022$, $F=14.82$, 6 df) with good concordance of the three repeated measures (Kendall's Tau=0.823). Consequently, it was appropriate to apply a one-way repeated measures ANOVA on the log-transformed data (without the MHmm1 habitat). This analysis showed a significant difference ($p=0.004$, $F=2.62$, 12 df) in mean number of bird detections both by habitat type and time (May–July).

A similar test conducted on all habitats but for the second and third repeated measures only (June–July), revealed that the within-subject terms (variation by time) were not significant ($p=0.082$, $F=1.90$, 7 df). Therefore, the second and third repeated measures were pooled and a simple one-way ANOVA for all habitats indicated a significant difference ($p<0.001$, $F=14.89$, 7 df) in mean number of bird detections. This finding necessitated the application of the Tukey post-analysis multiple means test, which revealed the following habitat associations (homogeneous groups are underlined).

MHmm1 CWHvm2 d/sd w f hardwood m/vm clearcut

Mean number of bird detections in the MHmm1 habitat was clearly different from any of the other habitats ($p\leq 0.002$; see Appendix 6). As well, the CWHvm2 habitat was significantly different ($p=0.026$) from the clearcut habitat type.

TABLE 5 Mean number of bird detections by species per census point in various habitats at Tofino Creek, Vancouver Island, 1992

Species code*	Habitat							
	Dry/ slightly dry	Fresh	Moist/ very moist	Wet	Hard- wood	Clearcut	CWH vm2	MH mm1
AMRO	0.79	0.71	1.30	1.19	1.53	1.30	0.43	0.00
BAEA	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
BEKI	0.02	0.00	0.03	0.00	0.00	0.11	0.00	0.00
BLGR	0.29	0.00	0.13	0.03	0.33	0.19	0.96	0.63
BRCR	0.17	0.04	0.10	0.03	0.00	0.00	0.05	0.00
BTGW	0.21	0.24	0.30	0.33	1.20	0.19	0.00	0.00
BTPI	0.10	0.02	0.13	0.03	0.13	0.19	0.00	0.00
CBCH	0.40	0.38	0.47	0.33	0.00	0.00	0.51	0.06
CHSP	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
COLO	0.00	0.00	0.03	0.00	0.13	0.00	0.00	0.00
COME	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
CORA	0.00	0.00	0.03	0.00	0.20	0.00	0.00	0.00
DEJU	0.05	0.04	0.17	0.06	0.07	0.04	0.05	1.19
DOWO	0.05	0.02	0.00	0.00	0.00	0.07	0.00	0.00
FOSP	0.00	0.00	0.00	0.00	1.73	0.04	0.00	0.00
GCKI	0.07	0.24	0.13	0.25	0.00	0.00	0.20	0.06
GCSP	0.00	0.00	0.07	0.00	0.00	0.11	0.00	0.00
HAWO	0.24	0.13	0.03	0.08	0.13	0.11	0.10	0.13
HETH	0.10	0.22	0.13	0.17	0.40	0.22	0.76	1.13
HUVI	0.00	0.00	0.03	0.00	0.07	0.00	0.00	0.00
MAMU	0.19	0.00	0.00	0.00	0.00	0.11	0.00	0.00
MERL	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
MGWA	0.17	0.00	0.33	0.28	0.60	0.33	0.08	0.00
NOCR	0.00	0.00	0.00	0.00	0.13	0.15	0.00	0.00
NOFL	0.02	0.00	0.03	0.00	0.00	0.00	0.00	0.00
NPOW	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
NRWS	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
OCWA	0.21	0.04	0.03	0.03	0.07	0.04	0.00	0.00
OSFL	0.07	0.02	0.23	0.00	0.00	0.49	0.00	0.00
PISI	0.05	0.07	0.03	0.03	0.07	0.00	0.29	0.13
PIWO	0.02	0.04	0.00	0.00	0.13	0.07	0.04	0.00
PSFL	1.43	1.25	1.30	1.68	0.98	0.24	1.31	0.13
RBNU	0.05	0.00	0.00	0.00	0.00	0.00	0.03	0.00
RCKI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
RECR	0.02	0.07	0.07	0.08	0.00	0.00	0.70	0.19
RSTO	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
RUGR	0.00	0.00	0.00	0.08	0.53	0.00	0.00	0.00
RUHU	0.15	0.09	0.10	0.00	0.11	0.52	0.07	0.06
SOSP	0.08	0.01	0.00	0.00	0.00	1.02	0.00	0.00
STJA	0.33	0.04	0.10	0.17	0.00	0.52	0.10	0.19
SWTH	0.49	0.60	0.93	0.81	1.12	1.90	0.00	0.00
TOWA	0.02	0.04	0.00	0.11	0.00	0.00	0.00	0.00
TRSW	0.00	0.00	0.03	0.00	0.07	0.04	0.00	0.00
VASW	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VATH	1.71	2.31	1.91	1.51	0.62	1.24	2.17	0.19
WAVI	0.00	0.00	0.10	0.08	0.87	0.00	0.00	0.00
WETA	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
WIPL	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
WIWA	0.05	0.03	0.42	0.00	0.88	0.80	0.00	0.00
WIWR	2.91	3.40	3.47	2.04	1.69	2.95	0.79	1.56
WSOW	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
YEWA	0.00	0.00	0.07	0.11	0.00	0.07	0.00	0.00
Sum of mean numbers	10.61	10.41	12.63	9.50	13.95	13.40	8.73	5.75

* Species codes are defined in Appendix 4.

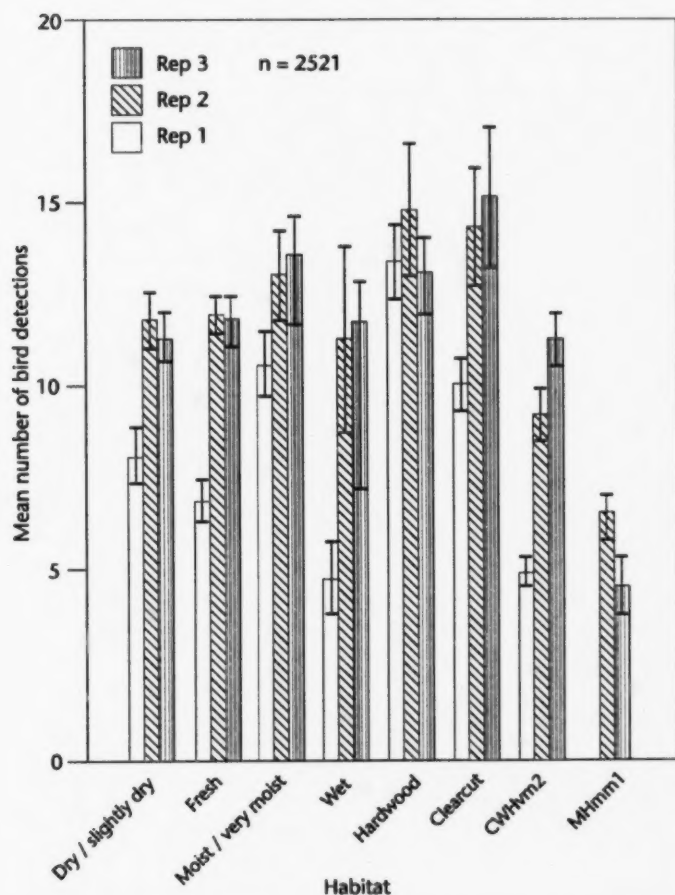


FIGURE 3 Mean number of bird detections (all species combined) per census point in various habitats at Tofino Creek, Vancouver Island, 1992.

Orthogonal comparisons of the homogeneous habitat groups indicated significant differences in mean bird detections for the following two contrasts (see Table 6):

Contrast 1: CWHvm2 versus CWHvh1/vm1 forested ($p=0.001$)

Contrast 3: Hardwood versus CWHvm1 coniferous ($p=0.017$)

TABLE 6 Orthogonal contrasts of homogeneous habitat groups at Tofino Creek, Vancouver Island, 1992

Contrast no.	Multivariate F	Probability (3.60 df)
1	6.122	0.001
2	1.453	0.237
3	3.667	0.017
4	0.517	0.672
5	1.135	0.342

4.1.2 Characteristic bird species by habitat type

CWHvm1 coniferous (dry/slightly dry, fresh, moist/very moist, wet)

Species characteristic of this variant were Brown Creeper, Chestnut-backed Chickadee, Golden-crowned Kinglet, Pacific-slope Flycatcher, Red-breasted Nuthatch, Varied Thrush, and Winter Wren.

CWHvm2 In addition to the species described above for the CWHvm1 variant, the CWHvm2 had the highest abundance levels of Blue Grouse, Pine Siskin, and Red Crossbill. Hermit Thrush was also common here.

Hardwood stands The deciduous hardwood habitat, found primarily along the Deer Bay estuary, had the highest mean total number of forest bird detections (13.95, $SE=1.29$, averaged for the three censuses) (Table 5 and Figure 3). It was characterized by birds such as Fox Sparrow, American Robin, Swainson's Thrush, Warbling Vireo, Ruffed Grouse, and six species of wood warblers.

Mean number of warbler detections (2.61, $SE=0.92$, averaged for the three censuses) was significantly higher in this habitat than in all others ($p=0.008$, Friedman $F=17.43$, 6 df; see Figure 4), with high concordance of the three repeated measures (Kendall's Tau=0.968).

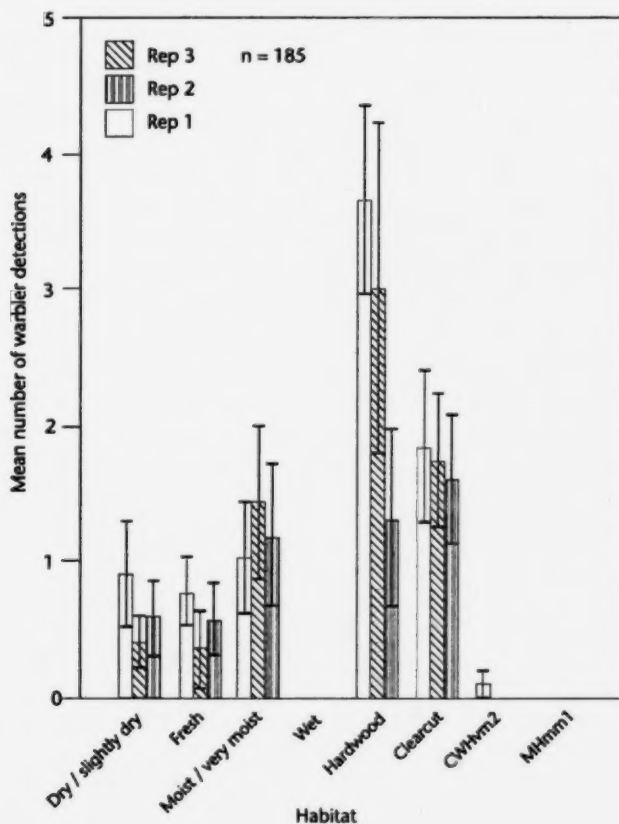


FIGURE 4 Mean number of warbler detections per census point in various habitats at Tofino Creek, Vancouver Island, 1992.

Clearcuts Clearcuts surveyed in Tofino Creek had the second highest mean total number of bird species detections (13.40, $SE=1.54$, averaged for the three censuses) (Table 5 and Figure 3). Clearcuts were characterized by species such as American Robin, Rufous Hummingbird, Olive-sided Flycatcher, Winter Wren, Swainson's Thrush, and Song Sparrow.

MHm1 This variant had the lowest mean total number of bird detections (5.75, $SE=0.724$, averaged for the June–July censuses) (Table 5 and Figure 3). It was characterized by species such as Hermit Thrush, Blue Grouse, Dark-eyed Junco, Pine Siskin, Ruby-crowned Kinglet, and Red Crossbill.

4.1.3 Abundance of selected bird species

Woodpeckers Mean number of woodpecker detections was highest in the d/sd coniferous (0.34, $SE=0.155$, averaged for the three censuses) and hardwood forest (0.31, $SE=0.31$) habitat types, followed by the CWHvm2 (0.24, $SE=0.18$; see Figure 5). No significant differences ($p=0.362$, Friedman $F=6.57$, 6 df) were observed in mean number of detections among the habitat types (MHm1 omitted), with low concordance between the three repeated measures (Kendall's Tau=0.365).

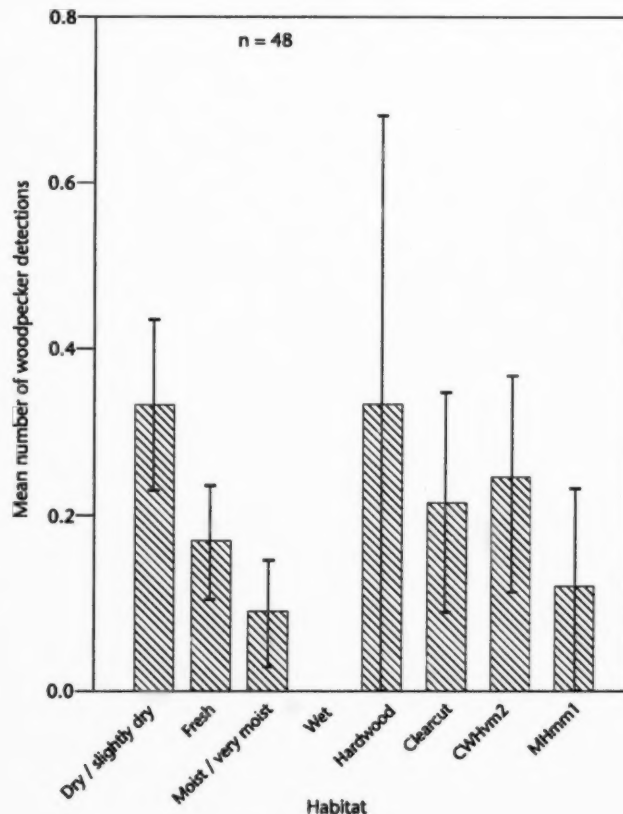


FIGURE 5 Mean number of woodpecker detections per census point in various habitats at Tofino Creek, Vancouver Island, 1992.

Other species Relative abundance of bird species considered to be early successional (e.g., Rufous Hummingbird, Song Sparrow), mid successional (e.g., Swainson's Thrush, Wilson's Warbler), and late successional (e.g., Pacific-slope Flycatcher, Varied Thrush) is illustrated in Figure 6. The Rufous Hummingbird (0.481 , $SE=0.177$, averaged for the three censuses) and Song Sparrow (1.000 , $SE=0.488$) had the highest mean number of detections in clearcuts. Swainson's Thrush and Wilson's Warbler were detected most frequently in the hardwood habitat (1.067 , $SE=0.340$; 0.890 , $SE=0.435$, respectively) and clearcuts (1.926 , $SE=0.467$; 0.800 , $SE=0.241$, respectively). The Pacific-slope Flycatcher and Varied Thrush

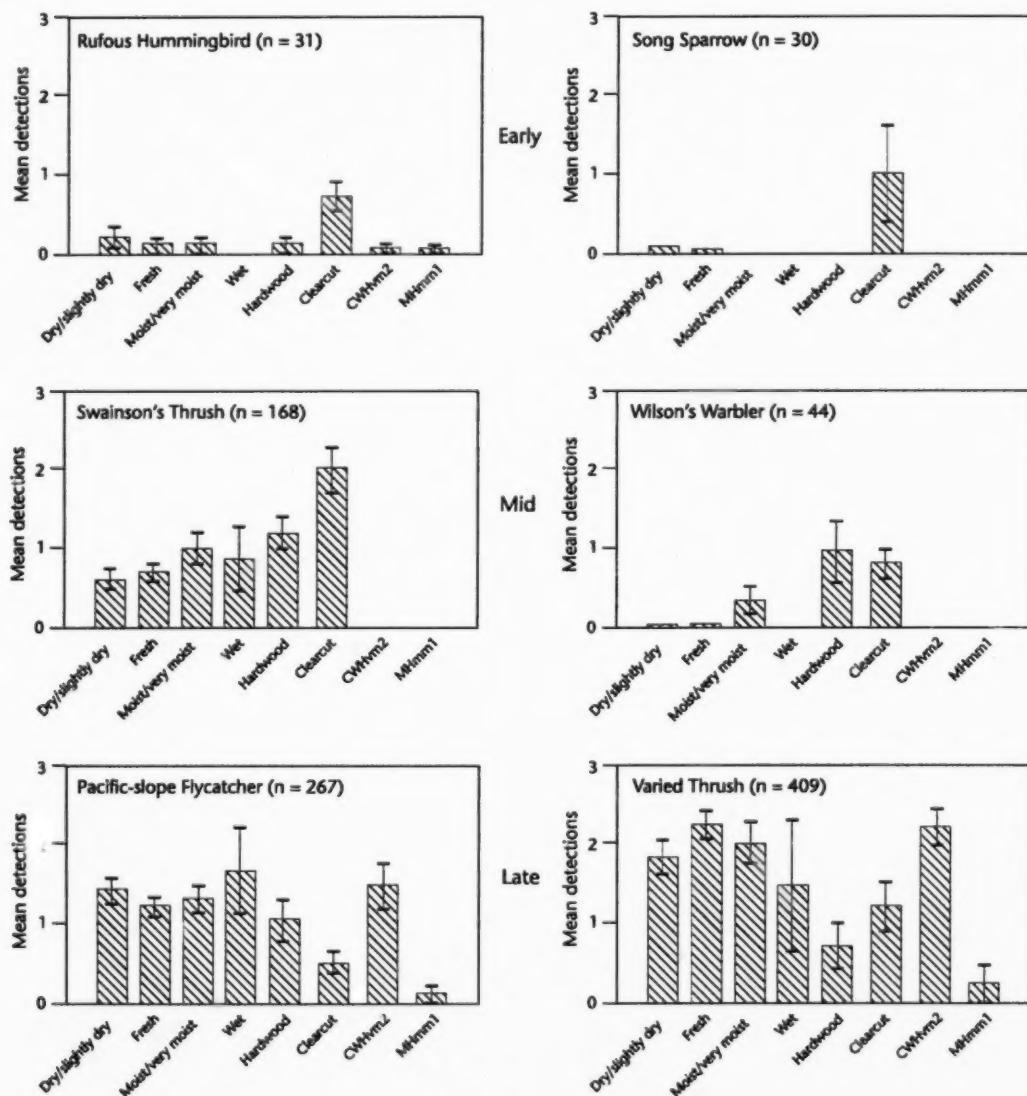


FIGURE 6 Early-, mid-, and late-successional bird species detections per census point in various habitats at Tofino Creek, Vancouver Island, 1992.

were most abundant in the old-growth coniferous CWHvm1 and CWHvm2 habitat types (see Figure 6). The ubiquitous Winter Wren was the most common forest bird observed, occurring 630 times (25% of all bird detections) and in all habitat types.

During the 2-day survey session, 81 murrelet detections were recorded with an average of 0.4 detections per survey station per minute. A minimum of 52 individual murrelets was observed during this period. The old-growth survey stations had the highest mean number of detections per census interval, while the forest edge, clearcut, and hardwood stations had lesser and nearly equal detection frequencies (Figure 7).

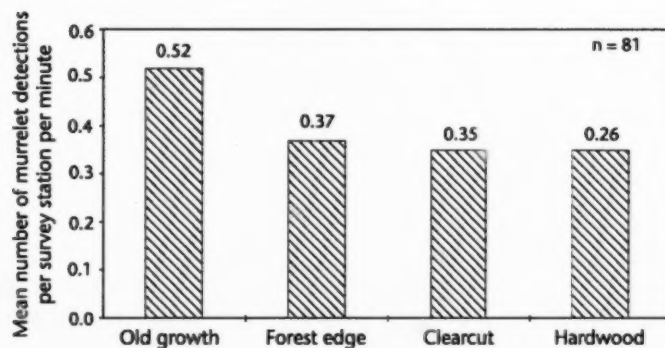


FIGURE 7 Mean number of murrelet detections in various habitats at Tofino Creek, Vancouver Island, 1992.

Birds were observed at horizontal distances ranging from 15 to 300 m. Most observations occurred at less than 100 m horizontally and greater than one tree height above the forest canopy (average 30–50 m overstory height). However, murrelet sightings at each station were generally too brief to yield conclusive information about habitat utilization. Survey station 5 (labelled Owl Station 5, located in old-growth 40–50 m tall Cw/Hw forest, 300 m in elevation; see Figure 2) had the greatest number of observations (17) over the two 10-minute census periods, necessitating a more intensive survey at this station (see section 4.2.1).

The most common behaviours detected were direct flights and overhead circling. Birds were sometimes silent but more often vocalized with diagnostic gull-like “keer” calls. Cloud cover was 90–100% during all murrelet observation periods.

4.2 Marbled Murrelet Survey

4.2.1 Single-day murrelet survey During the single-day murrelet survey on July 8, 1992, 39 observations of a minimum 54 individuals were recorded at station 5. The mean closest horizontal distance for birds observed during this session was 35 m, with birds generally flying greater than one tree height above the 50 m tall forest canopy. All vocalizations were the typical “keer” calls. Forty-four flight behaviours were observed. These consisted of 30 direct flights both to and from the sea (68%), 12 circling flights (27%), and two unknown overhead activities (5%). Cloud cover was 100%.

The 2-hour pre-dawn census conducted in the MHmm1 variant on July 10, 1992 yielded only one observation of an unknown number of birds calling while making an overhead flight from east to west. Cloud cover was again 100%.

4.3 Owl Surveys

Three species, including the Western Screech-Owl, Northern Saw-whet Owl, and Northern Pygmy-Owl responded to recorded playbacks. Twenty-five observations were recorded, consisting of 18 direct vocal responses, five fly-bys, and two individuals flying in and perching. On four occasions, two Western Screech-Owls responded to playbacks with alternate vocalizations. In total, 23 individual owls (17 Western Screech-Owls, four Northern Saw-whet Owls, two Northern Pygmy-Owls) were observed on 30 playback searches, resulting in a search effort of 0.77 individuals per search. The highest proportion (mean number of detections per survey station) of owl observations occurred in coniferous forest edge habitat, followed closely by old-growth. The hardwood and clearcut habitats had fewer detections, with detections in clearcuts likely resulting from birds being drawn in from adjacent forested habitats (Figure 8).

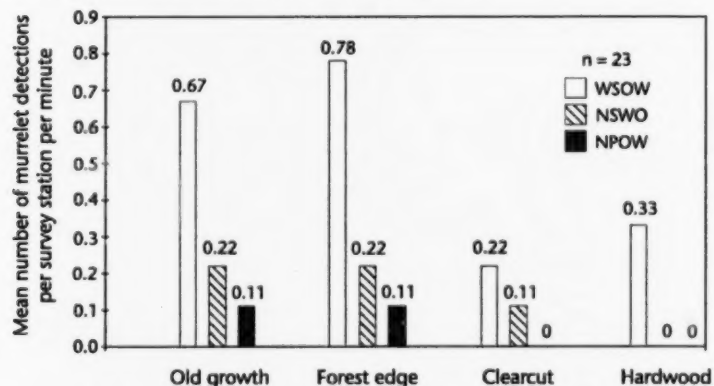


FIGURE 8 Mean number of owls detected in various habitats at Tofino Creek, Vancouver Island, 1992. (WSOW = Western Screech-Owl, NSWO = Northern Saw-whet Owl, NPOW = Northern Pygmy-Owl.)

Survey station 7 (four Western Screech-Owls and two Northern Pygmy-Owls) and station 5 (two Western Screech-Owls and two Northern Saw-whet Owls) accounted for most (43%) of the detections. Station 7 was located along the edge of an old-growth stand of 30–40 m tall Hw/Ba bordered on one side by clearcut, and station 5 was located in an old-growth stand of mixed 40–50 m tall Cw/Hw (see Figure 2). Both stations were in the CWHvm1.

Three Northern Pygmy-Owls were observed incidentally in the CWHvm2 while conducting the breeding bird survey.

4.4 Amphibian Searches

Thirty-three Western Red-backed and eight Clouded Salamanders were discovered during the amphibian searches, resulting in a search effort of 1.28 individuals per hour. All salamanders were discovered beneath or within partly decayed logs on the forest floor (log decay class 3; see Maser et al. 1979), or behind the loose bark of larger, less decayed logs (class 2) and stumps.

The wet (2.50), moist/very moist (2.00), and clearcut (1.50) habitats had the highest mean number of salamander detections per search effort (Figure 9). The montane CWHvm2 variant had the fewest detections (0.25).

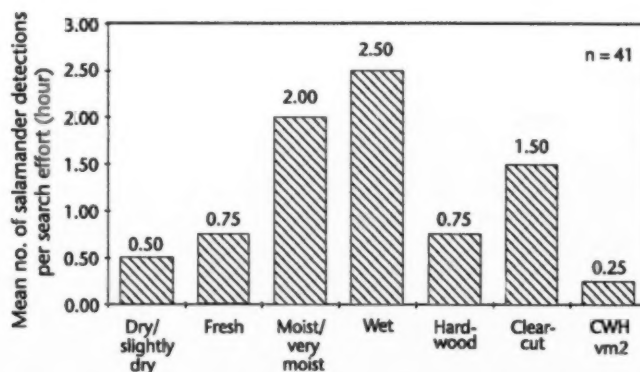


FIGURE 9 Mean number of salamander detections per search effort in various habitats at Tofino Creek, Vancouver Island, 1992.

4.4.1 Incidental salamander observations Numerous Northwestern Salamanders in earlier stages of development (neotenic) were observed in shallow meltwater/rainwater pools in the MHmm1 variant. Most pools greater than 0.5 m in depth and with a silt bottom contained these neotenic salamanders. Individuals ranged in size from 5 to 15 cm in length and had external gills. Northwestern Salamanders likely overwinter (aestivate) in the silty substrate on the bottom of these pools.

One Rough-skinned Newt was observed in a shallow, spring-fed pool in the hanging valley above Virgin Falls. This valley has a varied topography, with a dominant forest overstory of mature or old-growth western hemlock/amabilis fir, and some wet seepage micro-habitats.

4.5 Small Mammal Survey

The dry/slightly dry and clearcut habitats had the highest capture success rates for Deer Mice (17%, or 0.17 captures per trap night). Overall trap success for Deer Mice was 67 captures per 617 trap nights, or 11%. Eighty-eight percent of these captures occurred in Sherman traps, while 12% were in pit-falls.

Twelve shrews were captured in pitfall traps at the hardwood and wet/floodplain trap site locations. Six Ermine were captured in Sherman traps at the wet/floodplain and fresh trap sites.

Capture success by habitat type and trap type is summarized in Table 7.

4.6 Incidental Mammal Observations

Sixty-nine incidental observations, including visual sightings, tracks, and scats, were made of Black Bear (35), Cougar (two), Marten (one), Black-tailed Deer (nine), and Red Squirrel (22) in the Tofino Creek watershed.

4.6.1 Bears Black Bear was the most frequently observed mammal (excluding mice) and was seen in all habitat types in the Tofino Creek valley. Of 35 records, 27 were visual, while eight were either tracks, mark trees, day beds, or scats. Most sightings (85%) occurred along roads or trails within 50 m of forest cover. Two sightings occurred in dense patches of salmonberry, and two sightings occurred in mature forest cover (western hemlock/amabilis fir) near bird census point 63.

Investigation of bear scat content and direct feeding observation indicated a progression in diet as plant phenology changed over the season. In April and May, bears appeared to forage primarily on horsetail and sedge. Their

TABLE 7 Small mammal captures by habitat type and trap type at Tofino Creek, Vancouver Island, 1992

Habitat type (CWHvm1)	No. of Deer Mouse captures	No. of trap nights	Capture success (%)
Dry/slightly dry	6	35	17
Fresh	9	128	7
Wet/floodplain	17	179	9
Hardwood	12	143	8
Clearcut	23	132	17
Total	67	617	Mean=11%

Species	No. of captures	Sherman trap	Pitfall trap
Deer Mouse	67	59	8
Shrew	12	0	12
Ermine	6	6	0
Total	85	65	20

diet shifted to clover in late May and early June, and to salmonberries and thimbleberries throughout most of June and early July. Three fresh bear scats observed in the Mountain Hemlock zone in mid-June contained only sedges and horsetail, suggesting a slower progression in plant phenology at this elevation. A final dietary shift in July involved heavy foraging on *Vaccinium* spp., with minor feeding on salal and bunchberry.

A well-used bedding site was located under a large Sitka spruce in the narrow, forested riparian strip between the third and fourth bridges along Tofino Creek. Another well-used day bed, as well as a mark trail with noticeable pad marks and a mark tree (claw and bite marks in a 30 cm dbh Hw), were located in an old-growth Hw/Ba stand in the side valley east of the upper (fourth) bridge.

4.6.2 Other mammals Of nine observations of Black-tailed Deer, seven were tracks along roads, in dry streambeds, or on game trails through clearcuts. Two observations were of individuals feeding along clearcut road edges. Two observations of cougar tracks were made. One was in light snow along a rock bluff at approximately 600 m elevation in the CWHvm2 variant, and a second was found in mud along Tofino Creek in a mature stand of Hw/Cw near bird census point 63. One Marten track was observed in mud along Tofino Creek near Virgin Falls in an old-growth forest stand of Hw/Cw. Fur trapping records from 1990–1991 indicate that eight Marten were captured in old-growth forest stands along Tofino Creek (lower portion of the watershed along the Tofino mainline road) (N. Haider, pers. comm., 1992; registered trapline TRO108T403). Red Squirrels were observed on 22 occasions and were common in most habitat types. While conducting late evening owl surveys, bats (Order Chiroptera) were often observed flying and foraging along the road paralleling Tofino Creek in the lower portion of the watershed.

5 DISCUSSION

5.1 Forest Bird Abundance

The data obtained in this study indicate that the relative abundance and species composition of birds was similar ($p \geq 0.342$) between the four CWHvm1 coniferous habitats (d/sd, f, m/vm, wet). This either represents a true similarity in forest bird communities between these habitats, or else habitat differentiation by actual soil moisture regime was too fine and therefore did not provide a level of habitat resolution that was ecologically meaningful and interpretable. In two similar old-growth drainages in Clayoquot Sound (Bulson and Sydney watersheds), Bryant (1997) found that differences in bird relative abundances between stands is "quite small and largely caused by presence or absence of rare species." He found that bird communities are "dominated by a relatively small number of species that are abundant and widespread" (e.g., Winter Wren, Varied Thrush, Pacific-slope Flycatcher, Golden-crowned Kinglet, Chestnut-backed Chickadee), and that habitat variables such as vegetation structure explained only small amounts of the variation in abundance. Daust and Bunnell (1992) made similar conclusions, citing that forest stand measurements are poor predictors of abundance for most species, and that attempts to model bird communities on the basis of easily obtained habitat data may be premature, at least at the stand level. Coarser-scale habitat features such as physiography (e.g., rock outcrop, gully), elevation or slope position, presence of riparian areas, and forest age (successional stage) may be more reliable discriminatory variables.

The significant differences in relative bird abundance between the MHmm1 and all other habitat types, as well as the differences between the montane CWHvm2 and submontane CWHvm1 habitats, clearly indicate the changes in avian community structure in the higher-elevation habitats (MHmm1, CWHvm2). This is also reflected by the differences in bird species composition between the three variants. Even though the MHmm1 and CWHvm2 shared some of the same species with the CWHvm1, they contained birds that were absent or less abundant in the lower-elevation habitat types (e.g., Blue Grouse, Dark-eyed Junco, Hermit Thrush, Pine Siskin, Red Crossbill).

The high relative abundance and species diversity of birds observed in the hardwood habitat is in concurrence with the growing body of research indicating the importance of these areas for wildlife (Ohmart and Anderson 1982; Eckert et al. 1992; Enns et al. 1993). In this study, some bird species that were relatively common in the hardwood habitat, including warblers (Figure 4), vireos, sparrows and Ruffed Grouse, were found in low numbers or were absent in the other habitat types.

The relatively high relative abundance levels and species diversity of forest birds found in young seral clearcuts in this study is consistent with other studies of forest bird communities on Vancouver Island (Eckert et al. 1992; Bryant et al. 1993; Bryant 1997). As with the hardwood habitat, the clearcuts showed a characteristic avifauna that was absent or had low abundance levels in other habitats (e.g., Olive-sided Flycatcher, Rufous Hummingbird, Song Sparrow). On southeastern Vancouver Island, Shepard and Manning (1998) found a similar assemblage of songbirds in clearcuts, birds that were either absent or at low abundance in adjacent coniferous forest habitats.

Certain bird species are clearly more dependent on forest successional stage than others (Figure 6). Pacific-slope Flycatcher, Varied Thrush, Brown

Creeper, and Red-breasted Nuthatch were more abundant in old-growth habitats, while some, such as Song Sparrow and Olive-sided Flycatcher, utilized clearcuts. Others, such as American Robin, Swainson's Thrush, and Wilson's Warbler, were found in most habitats (with the exception of the CWHvm2 and MHmm1), but preferred early- to mid-successional clearcut and hardwood areas.

The detectability of some bird species can be influenced by the position of the observer relative to particular habitat features (e.g., forest edge and forest patches), proximity to large openings (e.g., clearcuts or windthrow areas), and topography. As well, presence of edge and the size of forest patches can affect bird community composition, abundance, and ecology (Whitcomb et al. 1981; Kroodsma 1984; Millikin 1993). These variables may explain the relatively high abundance of woodpeckers detected in clearcuts in this study (0.22 detections per census point; Figure 5). This apparent use of clearcuts could have been real or may have been the result of observer bias associated with increased bird detections in clearcuts (i.e., there is better visibility, bird vocalizations carry further, birds use habitats along or near block edges). Nevertheless, the presence of woodpeckers in older-successional coniferous and hardwood stands in this study (Figure 5) is consistent with the habitat requirements of this guild. Hardwood stands provide important nesting habitat for woodpeckers (Keisker 1987; Steeger et al. 1996), while conifers (if nearby), often provide foraging opportunities. However, because of the small sample size for woodpecker detections ($n=48$) and the low concordance between the repeated measures (May–July), no inferences can be drawn about the relative abundance and habitat requirements of woodpeckers in the Tofino Creek watershed. In addition, because woodpeckers use resources that often have a patchy distribution (i.e., dead or decaying trees suitable for nesting and feeding), point count surveys tend to under-represent abundance estimates for this group (Bryant 1997).

In addition to the above differences in relative bird abundance between habitats, the within-subject variability (by time) between the first census period (May) and the remaining two censuses (June–July) was significant ($p=0.004$, with MHmm1 omitted). Mean detection frequencies during the May bird census (see repeated measure 1, Figure 3) were consistently lower across the habitat types when compared to the later repeated measures. This was perhaps due to lower overall bird numbers at this time of year (given the later arrival and later territory establishment of some migrant species with few detections in early May [e.g., Pacific-slope Flycatcher, Swainson's Thrush], but with a much higher detection frequency in the latter two censuses).

Ultimately, the numerous and sometimes unknown factors that affect prey abundance and availability of suitable nesting and foraging habitat are likely the most important variables influencing forest bird abundance and distribution at the stand level.

5.2 Marbled Murrelets

Relatively few data on the breeding ecology and habitat requirements of Marbled Murrelets have been gathered. Data collected in this study indicate that Marbled Murrelets appear to use the Tofino Creek watershed in moderate numbers. The 39 murrelet observations obtained during the single-day (2-hour) survey represent a moderate number of detections compared to similar surveys conducted on western Vancouver Island (e.g., survey numbers have ranged from 10 to 80 observations per census period; D. Lindsay, Fletcher Challenge Ltd., Crofton, pers. comm., 1992 and R. McLaughlin,

MacMillan Bloedel Ltd., Nanaimo, pers. comm., 1992; see also Savard and Leman 1991). Most murrelet detections occurred along a valley-bottom stand of old-growth 40–50 m tall Cw/Hw, approximately 4 km up the Tofino Creek drainage from the estuary. Marbled Murrelets appear to rely on old-growth or mature forests for nesting habitat (Marshall 1988; Nelson 1989; Rodway et al. 1991). However, Paton et al. (1990) recommended that at least three or four surveys per transect be conducted before reliable conclusions regarding murrelet use of a particular area or stand can be reached, as do the current RIC standardized inventory methods (RIC 1997a). Thus, without additional, more intensive data collection, no further inferences about Marbled Murrelet habitat utilization or requirements in Tofino Creek can be made.

5.3 Owls

Coniferous forest edge and old-growth forest habitats had the highest mean detection rates for owls. Yet, while these data provide information on species presence/absence, they are insufficient to assess relative abundance of owls. The Western Screech-Owl appears to be the most common species in the Tofino Creek valley (16 of 23 detections). However, it is not known whether all owl species respond equally to audible playback tapes. The total number of observations may be conservative, since individual owls often respond to playbacks by silently flying by, undetected.

5.4 Salamanders

Most salamander detections occurred in moist/very moist and wet coniferous forest habitats as well as moist clearcut areas in the CWHvm1 variant. In clearcuts, salamanders were found where relatively moist micro-habitats existed under decaying logs and other large organic debris (where ASMR is moist to wet). Similar observations were made by Bryant (1992). Davis (1993) found a positive relationship ($r^2=0.77$) between the abundance of Western Red-backed Salamanders and amount of cover such as coarse woody debris, and number of sword fern bases.

Information about species presence/absence was obtained, but because of low sample sizes, data were insufficient to make conclusions about the relative abundance of salamanders in various habitat types. However, the data suggest that Western Red-backed and Clouded Salamanders were least abundant in drier, low-elevation sites, and also in higher-elevation habitats such as the CWHvm2 variant.

The limited-time search technique for inventorying salamanders was very labour intensive. Although the detection success ratio obtained in the current study was adequate, there may be more efficient and meaningful survey methods, such as night-time road searches following rainfall (RIC 1999; S. Orchard, pers. comm., July 1992;), and the use of artificial cover objects (Davis 1993).

5.5 Small Mammals

The clearcut and dry/slightly dry CWHvm1 forest habitats had the highest capture success ratios for small mammals such as Deer Mice. Although captures were recorded at all other habitat types, because of the limited trapping effort only presence/absence can be determined for mice in these habitats.

5.6 Black Bears

Black Bear was the most frequently observed large mammal in the watershed, being seen in all habitat types including the MHmm1 variant. However, without more in-depth research involving animal capture and radio-tagging, or hair sampling (DNA analysis), it is difficult to estimate bear populations in the valley or compare relative habitat utilization. Individual bears may have

been seen on several occasions, thus influencing estimates of population size. Bears are opportunistic feeders and are capable of utilizing a variety of habitats, especially as plant phenology changes throughout the year (Manning 1985; Rogers 1987; Nagy and MacHutchon 1991; Gunson 1993). This may account for their high visibility in the clearcuts and along roads during the spring and early summer. Observations decreased later in the summer as bear foraging shifted to *Vaccinium* spp., a shrub more commonly found in forested areas.

5.7 Limitations of the Study

As calculated in this study, mean number of forest bird detections per census point was used as an estimate of relative abundance, permitting comparison of bird numbers among habitats. However, this index does not provide a measure of absolute numbers of birds per census point or per habitat.

The sample size of forest breeding bird detections in this study was adequate to make comparisons of relative bird abundance among habitats in Tofino Creek. It is uncertain if, although likely that, the range of habitat types sampled in Tofino Creek is representative of other coastal forest ecosystems on Vancouver Island. Therefore, the following variables should be considered when applying the results of this study, and their interpretation, to other forest ecosystems. 1) Periodic annual fluctuations or eruptions in bird populations have been observed and can vary with such factors as food supply, weather conditions, seral stage, and bird species (Bock and Lepthien 1976; Helle and Monkkonen 1986; Holmes et al. 1986). Therefore, significant changes in relative abundance of some species of birds can occur among years (Carey et al. 1991), potentially skewing the interpretation of survey data, especially in single-year studies such as this. 2) The difficulty in selecting bird census points based on actual soil moisture regimes that were often variable (especially for the wet coniferous habitat types) resulted in a skewed (i.e., higher) number of fresh CWHvm1 census points in the total sample. Therefore, the use and validity of ASMR as a reliable habitat classifier for bird abundance measures should be considered carefully.

Some bird species, such as swallows and swifts, nuthatches, chickadees, Golden-crowned Kinglet, jays, and woodpeckers, which are difficult to detect because of their lack of song or indistinguishable songs and calls, may be underestimated in this study. Bryant (1997) suggested a similar under-estimation for these species and others, where point count censuses are used. As well, variable and steep topography, as found in Tofino Creek, may affect bird detections. On steep slopes, few birds are detected above the observer, creating a downward bias in estimates of relative abundance (Bryant et al. 1993).

The small sample sizes obtained for the Marbled Murrelet, owl, amphibian, and small mammal surveys provided useful information on species presence/absence, but were insufficient to draw conclusions about the relative abundance of these animals in the Tofino Creek watershed.

6 CONCLUSIONS

The Mountain Hemlock habitat had the lowest mean total number of bird detections. Significant differences ($p \leq 0.002$) in relative abundance of forest birds were determined between this and all other habitat types. Forest bird abundance also differed significantly between the montane CWHvm2 and the submontane CWHvm1 forested ($p = 0.001$) and clearcut ($p = 0.026$)

habitats. The two higher-elevation habitats (MHmm1 and CWHvm2), while having some species overlap with the CWHvm1, were characterized by a different species composition. This finding should be taken into consideration when planning the locations of forest management leave areas at the landscape level (e.g., leave strategies such as Forest Ecosystem Networks³ should be designed to include both valley-bottom and middle- to high-elevation forest stands).

The four CWHvm1 coniferous habitats (dry/slightly dry, fresh, moist/very moist, wet) had similar ($p \geq 0.342$) mean relative abundance levels. The clearcut habitat had a relatively high relative abundance and diversity of bird species and did not differ significantly ($p = 0.237$) from the forested (hardwood and coniferous) habitats. Clearcuts were characterized by early successional bird species that were less abundant in other habitats. The hardwood habitat had the highest mean number of bird detections and differed significantly ($p = 0.017$) from the coniferous forest habitats. The hardwood habitat contained species, such as warblers, that were absent or occurred at low levels in the other habitats. Surveys for Marbled Murrelets, owls, salamanders, and small mammals provided useful information on the presence/absence of these species in various habitats in the watershed. However, without larger sample sizes and more rigorous field censusing, no conclusions about their relative abundance can be made. The use of actual soil moisture regime (ASMR) as a criterion for differentiating coastal forest habitats may not be satisfactory when attempting to assess animal abundance in these habitats.

7 RECOMMENDATIONS FOR FURTHER RESEARCH

1. Additional research is needed to compare disturbed and undisturbed ecosystems in low-elevation coastal forests. Because of the fragmented nature of the wet/floodplain coniferous habitat in the lower and mid-sections of Tofino Creek (from previous timber harvesting) and the variability in classifying these habitats by ASMR, interpretation of data obtained from these areas will be most useful when the data are compared to a similar valley-bottom habitat in an undisturbed ecosystem. The adjacent Clayoquot, Megin, and Moyeha watersheds are potential candidates, because they represent similar Coastal Western Hemlock ecosystems.
 2. The relative abundance and distribution of owls needs to be determined in more detail. Research should focus on obtaining a better understanding of habitat preferences and elevational differences in species abundance and composition.
 3. In this study, correlation of forest structural characteristics (e.g., tree species composition, tree size and height, canopy closure and layering, understory vegetation, snags, coarse woody debris) with bird presence, abundance, and distribution was not investigated. Analyses of this kind, although potentially difficult due to the many variables involved, should
- 3 Forest Ecosystem Network—a planned landscape zone that serves to maintain or restore the natural connectivity within a landscape unit. A Forest Ecosystem Network can consist of a variety of protected areas, special management areas, sensitive areas, or old-growth management areas.

be undertaken and should include comparisons of mean detections by habitat type for all bird species (pooled) as well as for specified guilds (e.g., woodpeckers, forest songbirds).

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APPENDIX 1 Floral species list

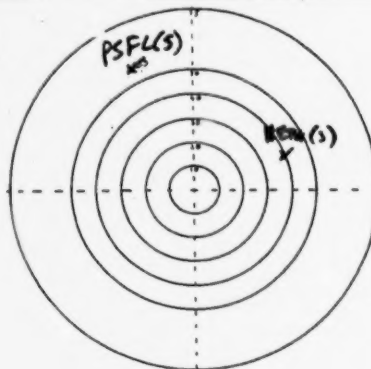
Common Name	Scientific Name
Mosses/Herbs/Shrubs	
blueberry	<i>Vaccinium</i> spp.
bunchberry	<i>Cornus canadensis</i>
deer fern	<i>Blechnum spicant</i>
devil's club	<i>Oplopanax horridus</i>
false-lily-of-the-valley	<i>Maianthemum dilatatum</i>
fireweed	<i>Epilobium angustifolium</i>
lady fern	<i>Athyrium filix-femina</i>
lanky moss	<i>Rhytidiadelphus loreus</i>
one-leaved foamflower	<i>Tiarella unifoliata</i>
red elderberry	<i>Sambucus racemosa</i>
salal	<i>Gaultheria shallon</i>
salmonberry	<i>Rubus spectabilis</i>
sword fern	<i>Polystichum munitum</i>
thimbleberry	<i>Rubus parviflorus</i>
Trees	
amabilis fir	<i>Abies amabilis</i>
black cottonwood	<i>Populus balsamifera</i> subsp. <i>trichocarpa</i>
mountain hemlock	<i>Tsuga mertensiana</i>
red alder	<i>Alnus rubra</i>
Sitka spruce	<i>Picea sitchensis</i>
western hemlock	<i>Tsuga heterophylla</i>
western redcedar	<i>Thuja plicata</i>
yellow-cedar	<i>Chamaecyparis nootkatensis</i>

APPENDIX 2 Standard data forms

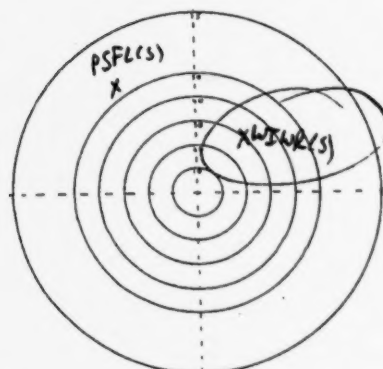
PLOT: 6 STATION NO.: — DATE: Jan 7 TIME-START: 0658 END: 0710 OBSERVER(S): TM
 WEATHER: Foggy COMMENTS: VM2 - M-M

N
↑

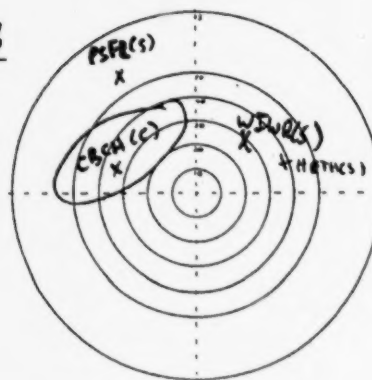
INT. 1



TANU in plot (C)



INT. 3



MARBLED MURRELET DETECTION FORM

Page 1 of 2

Watershed: Tapiro Creek into CWHVM, (300 m elev.)
 Site: Approx. 5 km up drainage from estuary Date: 92/07/08 Observer: TODD HANNING
 Transect: _____ Fixed station: Sta. #5 (CWHVM)
 Time start: 0440 End: 0621 Official sunrise: 0520
 % cloud: begin: 100 end: 100 Precipitation: begin: N end: N Wind: begin: 0 end: 0

12	13	14	15	16	17	18	19	20	21	
Stat	Detect	Time	Direction	Calls	#	Total	Beha-	Clos-		
#	#		From To	# Type	seen	est. # birds	vior	est. Dist. (m)	Height (m)	Comments
S	1	0450	E W	3 K	0	4	D	50	A	50 m canopy
S	2	0454	E W	3 K	2	2	D	30	A	
S	3	0458	E W	2 K	3	3	D	25	A	
S	4	0501	SW NE	4 K	2	2	D	40	A	
S	5	0504	SW NE	8 K	2	2	C,D	65	A	
S	6	0506	SW NE	6 K	2	2	C	60	A	
S	7	0509	SW NE	3 K	0	4	U	35	A	
S	8	0512	SW NE	2 K	0	4	U	55	A	
S	9	0514	SW NE	3 K	2	2	D	0	A	
S	10	0516	SW NE	7 K	2	2	C	15	A	
S	11	0518	SW NE	M K	3	3	C,D	30	A	
S	12	0520	SW NE	6 K	3	3	C	30	A	
S	13	0520	SW NE	7 K	2	2	D	25	A	
S	14	0521	SW NE	2 K	0	1	D	20	A	
S	15	0522	SW NE	4 K	0	1	D	40	A	
S	16	0525	SW NE	4 K	0	4	D	50	A	
S	17	0526	NE SW	5 K	0	4	D	40	A	
S	18	0528	SW NE	10 K	0	1	D	40	A	
S	19	0529	SW NE	7 K	1	2	D	35	A	
S	20	0530	SW NE	M K	7	7	C,D	45	A	
S	21	0530	SW NE	4 K	2	2	D	30	A	
S	22	0531	SW NE	3 K	1	1	D	40	A	
S	23	0533	SW NE	5 K	0	4	D	40	A	

Height:

A=>1 tree height above canopy;

B=<1 tree height above canopy;

C=below canopy;

E=enter canopy;

I=exit canopy;

U=unknown.

Call type:

K=typical kee call;

A=alternate quack-type call;

S=single isolated kee (emphatic and sometimes cut short);

W=wingbeats;

J=jet sound;

when more than 1 type is heard in a detection,

use 2 or 3 lines; when detection is also visual use

V in front of type letter (VK,VA,etc.)

Behaviour:

D=direct flight;

C=circle;

L=land;

S=call from stationary point;

A=aerial dive;

U=unknown.

Precip.

W=none;

F=fog;

D=drizzle;

R=rain.

Wind: see over.

HARBLED MURRELET DETECTION FORM

Page 2 of 2

Watershed: Tolino Creek Year/Month/Day _____
 Site: Approx. 5 km up drainage from study Date 9/2/07/08 Observer TODD HANNING
 Transect _____ Fixed station Sta. #5 (CWN vrn.)
 Time start 0440 End 0624 Official sunrise 0520
 % cloud: begin: 100 Precipitation: begin: N Wind: begin: 0
 end: 100 end: _____ end: 0

12	13	14	15	16	17	18	19	20	21			
Stat #	Detect #	Time	Direction		Calls		Total # seen	Total est.# birds	Behav- ior	Clos- est Dist. (m)	Height (m)	Comments
			From	To	#	Type						
S	24	0532	SW	NE	5	K	0	4	D	35	A	SO m canopy.
S	25	0533	S	N	4	E	2	2	D	40	A	
S	26	0534	N	E	12	E	0	4	D	30	A	
S	27	0534	N	E	5	K	2	2	D	25	C	
S	28	0534	S	N	10	E	3	3	D	20	B	
S	29	0539	SW	NE	3	K	1	1	D	35	A	
S	30	0541	N	E	2	K	1	1	G, O	40	A	
S	31	0542	SW	NE	5	K	0	4	D	30	A	
S	32	0544	NE	SW	6	K	0	4	O	25	A	
S	33	0546	S	N	8	K	2	2	C	35	A	
S	34	0550	NE	SW	5	K	0	4	D	20	A	
S	35	0553	N	E	4	K	0	4	D	30	A	
S	36	0554	N	E	6	K	2	2	C	10	A	
S	37	0555	SW	NE	8	K	0	4	C	40	A	
S	38	0601	SW	NE	3	K	2	2	C	40	A	
S	39	0601	N	E	1	K	1	1	C	20	A	
												No detections after 0601 hours.

Weight:

```
A=>1 tree height above canopy;  
B=<1 tree height above canopy;  
C=below canopy;  
E=enter canopy;  
I=exit canopy;  
Unknown
```

Call type:

```

Labels:
S=typical kear call;
A=alternate quack-type call;
S=single isolated kear type (emphatic and sometimes cut short);
W=wingbeats;
J=jet sound;

  when more than 1 type is heard in a detection,
  use 2 or 3 lines; when detection is also visual use
  v in front of type letter (VK,VA,etc.)

```

Behaviour:

D=direct flight;
C=circle;
L=land;
S=call from stationary point;
A=aerial dive;
U=unknown.

Precip.

Precip. N=none;
F=fog;
D=drizzle;
R=rain.

Wind: see over.

APPENDIX 3 Breeding bird census point descriptions

Plot no.	Biogeoclimatic variant	SNR*	ASMR†	Slope (%)	Aspect (deg.)	Elevation‡ (m)	Crown closure (%)	Understory description
1	CWHvm1	poor	slightly dry	70	280	NR	45	Not described
2	CWHvm1	medium	fresh	25	340	NR	30	60% <i>Vaccinium</i> spp. ground cover
3	CWHvm1	medium	moist	3	192	NR	35	<i>Blechnum spicant</i> , <i>Vaccinium</i> spp. ~75% ground cover
4	CWHvm1	rich	very moist	0	level	NR	30	80% <i>Polystichum munifolium</i> ground cover
5	CWHvm2	poor	slightly dry	40	50	NR	35	70% <i>Gaultheria shallon</i> ground cover
6	CWHvm2	medium	moist	50	300	485	35	<i>Vaccinium</i> spp., <i>Polystichum munifolium</i> – variable ground cover
7	CWHvm2	poor	fresh	60	220	NR	20	<i>Vaccinium</i> spp., <i>Blechnum spicant</i>
8	CWHvm2	medium	fresh	50	205	NR	35	<i>Vaccinium</i> spp., <i>Gaultheria shallon</i> , <i>Blechnum spicant</i>
9	CWHvm2	medium	slightly dry	30	20	NR	20	<i>Gaultheria shallon</i> , <i>Blechnum spicant</i> , <i>Vaccinium</i> spp.
10	CWHvm2	medium	moist	30	172	NR	55	<i>Vaccinium</i> spp., <i>Oplopanax horridus</i>
11	CWHvm2	poor	slightly dry	50	350	600	25	15–20% <i>Gaultheria shallon</i> ground cover
12	CWHvm2	rich	very moist	35	35	520	20	90–95% <i>Hylocomium splendens</i> , <i>Coptis asplenifolia</i>
13	CWHvm2	medium	slightly dry	55	360	550	30	<i>Gaultheria shallon</i> (variable)
14	CWHvm2	medium	moist	20	225	NR	20	Not described
15	CWHvm1	medium	slightly dry	0	level	270	20	60% <i>Gaultheria shallon</i> ground cover
16	CWHvm1	medium	slightly dry	60	300	NR	25	<i>Gaultheria shallon</i> , some <i>Vaccinium</i> spp.
17	CWHvm1	poor	slightly dry	90	180	NR	25	<i>Gaultheria shallon</i> , <i>Blechnum spicant</i>
18	CWHvm1	medium	fresh	10	216	275	25	<i>Gaultheria shallon</i> , <i>Vaccinium</i> spp., <i>Blechnum spicant</i> co-dominant ground cover
19	CWHvm1	poor	slightly dry	60	90	280	25	50% <i>Gaultheria shallon</i> ground cover
20	CWHvm1	medium	slightly dry	40	182	NR	75	<i>Polystichum munifolium</i>
21	CWHvm1	medium	fresh	5	310	NR	60	75% <i>Gaultheria shallon</i> ground cover
22	CWHvm1	medium	moist	0	level	NR	70	<i>Vaccinium</i> spp., <i>Blechnum spicant</i>
25	CWHvm1	medium	slightly dry	5	180	NR	40	<i>Gaultheria shallon</i>
26	CWHvh1/ clearcut	poor	slightly dry	0	level	10	0	90% <i>Gaultheria shallon</i> ground cover, <i>Alnus rubra</i> sub-canopy
27	CWHvh1/ hardwood	medium	very moist	25	variable	5	15	Mixed deciduous
28	not established			0			0	Not applicable
29	CWHvm1	poor	slightly dry	70	350	NR	10	<i>Gaultheria shallon</i>
30	CWHvm1	medium	moist	0	level	NR	20	<i>Polystichum munifolium</i> , <i>Rubus parviflorus</i>
31	CWHvm1	medium	moist	0	level	NR	80	<i>Polystichum munifolium</i> , <i>Vaccinium</i> spp., <i>Blechnum spicant</i>

* Soil Nutrient Regime

† Actual Soil Moisture Regime

‡ NR – not recorded

APPENDIX 3 Continued

Plot no.	Biogeoclimatic variant	SNR*	ASMR†	Slope (%)	Aspect (deg.)	Elevation‡ (m)	Crown closure (%)	Understory description
32	CWHvml	medium	moist	10	265	80	45	Not described
33	CWHvml	medium	fresh	15	295	NR	45	30% <i>Blechnum spicant</i> ground cover
34	CWHvml	medium	moist	5	level	NR	35	<i>Polystichum munitum</i> , <i>Blechnum spicant</i> , <i>Rubus parviflorus</i> – 45% ground cover
35	CWHvml	medium	moist	50	120	NR	70	<i>Blechnum spicant</i> , <i>Polystichum munitum</i>
36	not established			0				Not applicable
37	CWHvml	medium	fresh	55	95	NR	50	55% <i>Vaccinium</i> spp., <i>Gaultheria shallon</i> , <i>Blechnum spicant</i> ground cover
38	CWHvml	poor	slightly dry	20	180	NR	25	75% <i>Gaultheria shallon</i> ground cover
39	CWHvml	poor	slightly dry	60	350	NR	50	55% <i>Gaultheria shallon</i> , <i>Vaccinium</i> spp., <i>Cornus canadensis</i>
40	CWHvml/ clearcut	medium	fresh	90	320	NR	0	40% <i>Blechnum spicant</i> , <i>Vaccinium</i> spp., <i>Gaultheria shallon</i>
41	CWHvml	poor	slightly dry	40	20	NR	45	40% <i>Vaccinium</i> spp., <i>Gaultheria shallon</i> , <i>Polystichum munitum</i>
42	CWHvml	medium	moist	10	100	NR	30	65% <i>Polystichum munitum</i> , <i>Vaccinium</i> spp., <i>Rubus parviflorus</i>
43	CWHvml	rich	very moist	0	level	NR	50	<i>Maianthemum dilatatum</i> , <i>Vaccinium</i> spp., <i>Athyrium filix-femina</i> – 80% ground cover
44	CWHvml/ clearcut	medium	fresh	20	275	NR	0	<i>Gaultheria shallon</i> , <i>Vaccinium</i> spp. – 30% ground cover
45	CWHvml	medium	fresh	40	115	NR	35	<i>Rubus parviflorus</i> , <i>Vaccinium</i> spp., <i>Polystichum munitum</i> , <i>Gaultheria shallon</i> – 75% ground cover
46	CWHvml	rich	very moist	2	140	NR	60	<i>Athyrium filix-femina</i> , <i>Polystichum munitum</i> , <i>Vaccinium</i> spp. – 70% ground cover
47	not established							Not applicable
48	not established							Not applicable
49	not established							Not applicable
50	CWHvml	very rich	fresh	0	level	60	60	<i>Rubus</i> spp., <i>Blechnum spicant</i> , <i>Vaccinium</i> spp.
51	CWHvml	very rich	fresh	0	level	60	50	<i>Athyrium filix-femina</i>
52	CWHvml	very rich	fresh	0	level	60	15	<i>Rubus</i> spp., <i>Polystichum munitum</i> , <i>Trautvetteria carolinensis</i>
53	CWHvml	rich	fresh			NR	60	<i>Rubus</i> spp., <i>Vaccinium</i> spp., <i>Athyrium filix-femina</i> , <i>Maianthemum dilatatum</i>
54	CWHvml	rich	fresh	15	135	NR	65	<i>Vaccinium</i> spp., <i>Polystichum munitum</i> , <i>Blechnum spicant</i>
55	CWHvml	medium	fresh	15	315	95	80	<i>Vaccinium</i> spp., <i>Blechnum spicant</i> , <i>Polystichum munitum</i> , <i>Vaccinium parvifolium</i>
56	CWHvml	medium	fresh	40	315	120	75	<i>Vaccinium</i> spp., <i>Blechnum spicant</i> , <i>Vaccinium parvifolium</i>

* Soil Nutrient Regime

† Actual Soil Moisture Regime

‡ NR – not recorded

APPENDIX 3 Continued

Plot no.	Biogeoclimatic variant	SNR*	ASMR†	Slope (%)	Aspect (deg.)	Elevation‡ (m)	Crown closure (%)	Understory description
57	CWHvml	medium	fresh	50	300	150	80	<i>Vaccinium</i> spp., <i>Gaultheria shallon</i> , <i>Blechnum spicant</i> , <i>Vaccinium parvifolium</i>
58	CWHvml	medium	fresh	20	340	150	75	<i>Vaccinium</i> spp., <i>Blechnum spicant</i> , <i>Vaccinium parvifolium</i> , <i>Kindbergia oregana</i>
59	CWHvml	medium	fresh	35	320	100	80	<i>Vaccinium</i> spp., <i>Blechnum spicant</i> , <i>Vaccinium parvifolium</i>
60	CWHvml	rich	fresh	0	level	65	70	<i>Vaccinium</i> spp., <i>Rubus</i> spp., <i>Polystichum munitum</i>
61	CWHvml	very rich	fresh	3	270	60	60	<i>Vaccinium</i> spp., <i>Rubus</i> spp., <i>Blechnum spicant</i> , <i>Tiarella unifoliata</i> , <i>Athyrium filix-femina</i>
62	CWHvml	medium	fresh	5	290	NR	50	<i>Vaccinium</i> spp., <i>Blechnum spicant</i> .
63	CWHvml	medium	fresh	40	220	NR	50	<i>Gaultheria shallon</i> , <i>Vaccinium</i> spp.
64	CWHvml	medium	fresh	10	180	NR	70	<i>Vaccinium</i> spp., <i>Blechnum spicant</i>
65	CWHvml	medium	very moist	10	290	NR	50	55% <i>Blechnum spicant</i> , <i>Polystichum munitum</i>
66	CWHvml	rich	w	10	325	NR	60	<i>Vaccinium</i> spp., <i>Blechnum spicant</i> . ~70% ground cover
67	CWHvml	rich	w	0	level	NR	70	<i>Polystichum munitum</i> , <i>Blechnum spicant</i> ~ 80% ground cover
68	CWHvml/ clearcut	rich	w	0	level	NR	30	<i>Polystichum munitum</i> , <i>Rubus</i> spp., <i>Tiarella unifoliata</i> ~ 80% ground cover
69	CWHvhl/ hardwood	rich	very moist	0	level	NR	80	90% <i>Rubus</i> spp.
70	CWHvhl/ hardwood	rich	very moist	0	level	NR	50	100% <i>Rubus</i> spp., <i>Lathyrus nevadensis</i> , <i>Sambucus racemosa</i>
71	CWHvhl/ hardwood	rich	very moist	0	level	NR	60	50% <i>Maianthemum dilatatum</i> ground cover
72	CWHvhl/ clearcut	medium	moist	10	185	NR	0	<i>Vaccinium</i> spp., <i>Rubus</i> spp., <i>Tiarella unifoliata</i> , <i>Blechnum spicant</i> ~ 60% ground cover
73	CWHvhl/ hardwood	rich	moist	0	level	NR	50	<i>Rubus</i> spp., <i>Vaccinium</i> spp., ~ 85% ground cover
74	CWHvhl/ clearcut	medium	w	0	level	NR	0	<i>Rubus</i> spp., <i>Vaccinium</i> spp., <i>Athyrium filix-femina</i> ~ 85% ground cover
75	CWHvml/ clearcut	medium	moist	10	130	NR	0	<i>Rubus</i> spp., <i>Sambucus racemosa</i> ~ 70% ground cover
76	CWHvml/ clearcut	medium	moist	15	140	NR	0	<i>Epilobium angustifolium</i> , <i>Rubus</i> spp., <i>Polystichum munitum</i> ~ 65% ground cover
77	CWHvml/ clearcut	rich	w	0	level	NR	0	<i>Rubus</i> spp., <i>Polystichum munitum</i> , <i>Blechnum spicant</i> , <i>Sambucus racemosa</i> ~ 75% ground cover
78	not established							Not applicable

* Soil Nutrient Regime

† Actual Soil Moisture Regime

‡ NR = not recorded

APPENDIX 3 Concluded

Plot no.	Biogeoclimatic variant	SNR*	ASMR†	Slope (%)	Aspect (deg.)	Elevation‡ (m)	Crown closure (%)	Understory description
79	CWHvm1	medium	slightly dry	90	155	NR	30	<i>Gaultheria shallon</i> , <i>Vaccinium</i> spp. – 80% ground cover
80	not established			0			0	Not applicable
81	not established							Not applicable
82	not established							Not applicable
83	not established							Not applicable
84	not established							Not applicable
85	MHmml	poor	dry	90	280	1070	5	<i>Cassiope mertensiana</i> , <i>Vaccinium</i> spp.
86	MHmml	poor	dry	95	280	1060	30	<i>Vaccinium</i> spp.
87	MHmml	poor	fresh	70	300	1050	25	<i>Vaccinium</i> spp. – 90% ground cover
88	MHmml	poor	slightly dry	95	270	1050	50	<i>Abies rubra</i> , <i>Vaccinium</i> spp. – 50% ground cover
89	MHmml			95	300	1050	20	<i>Abies rubra</i> , <i>Vaccinium</i> spp. – 75% ground cover
90	MHmml	poor	slightly dry	10	31	1100	25	<i>Vaccinium</i> spp.
91	MHmml	poor	slightly dry	15	200	1100	20	<i>Vaccinium</i> spp.
92	MHmml	poor	slightly dry	5	50	1100	35	<i>Vaccinium parvifolium</i>

* Soil Nutrient Regime

† Actual Soil Moisture Regime

‡ NR – not recorded

APPENDIX 4 Faunal species list

Species code	Common name	Scientific name
Birds		
AMDI	American Dipper	<i>Cinclus mexicanus</i>
AMRO	American Robin	<i>Turdus migratorius</i>
BAEA	Bald Eagle	<i>Haliaeetus leucocephalus</i>
BAOW	Barred Owl	<i>Strix varia</i>
BEKI	Belted Kingfisher	<i>Ceryle alcyon</i>
BHGR	Black-headed Grosbeak	<i>Pheucticus melanocephalus</i>
BLGR	Blue Grouse	<i>Dendragapus obscurus</i>
BRCR	Brown Creeper	<i>Certhia americana</i>
	Black-throated Gray Warbler	<i>Dendroica nigrescens</i>
BTGW	Band-tailed Pigeon	<i>Columba fasciata</i>
BTPI	Chestnut-backed Chickadee	<i>Parus rufescens</i>
CBCH	Cedar Waxwing	<i>Bombycilla cedrorum</i>
CEWA	Chipping Sparrow	<i>Spizella passerina</i>
CHSP	Common Loon	<i>Gavia immer</i>
COLO	Common Merganser	<i>Mergus merganser</i>
COME	Common Raven	<i>Corvus corax</i>
CORA	Dark-eyed Junco	<i>Junco hyemalis</i>
DEJU	Downy Woodpecker	<i>Picoides pubescens</i>
DOWO	Fox Sparrow	<i>Passerella iliaca</i>
FOSP	Golden-crowned Kinglet	<i>Regulus satrapa</i>
GCKI	Golden-crowned Sparrow	<i>Zonotrichia atricapilla</i>
GCSP	Hairy Woodpecker	<i>Picoides villosus</i>
HAWO	Hermit Thrush	<i>Catharus guttatus</i>
HETH	Hutton's Vireo	<i>Vireo huttoni</i>
HUVI	Marbled Murrelet	<i>Brachyramphus marmoratus</i>
MAMU	Merlin	<i>Falco columbarius</i>
MERL	MacGillivray's Warbler	<i>Oporornis tolmiei</i>
MGWA	Northwestern Crow	<i>Corvus caurinus</i>
NOCR	Northern Flicker	<i>Colaptes auratus</i>
NOFL	Northern Pygmy-Owl	<i>Glaucidium gnoma swarthi</i>
NPOW	Northern Rough-winged Swallow	<i>Stelgidopteryx serripennis</i>
NRWS	Northern Saw-whet Owl	<i>Aegolius acadicus</i>
NSWO	Orange-crowned Warbler	<i>Vermivora celata</i>
OCWA	Olive-sided Flycatcher	<i>Contopus borealis</i>
OSFL	Pine Grosbeak	<i>Pinicola enucleator</i>
PIGR	Pine Siskin	<i>Carduelis pinus</i>
PISI	Pileated Woodpecker	<i>Dryocopus pileatus</i>
PIWO	Pacific-slope Flycatcher	<i>Empidonax difficilis</i>
PSFL	Red-breasted Nuthatch	<i>Sitta canadensis</i>
RBNU	Red-breasted Sapsucker	<i>Sphyrapicus ruber</i>
RBSA	Ruby-crowned Kinglet	<i>Regulus calendula</i>
RCKI		

APPENDIX 4 Continued

Species code	Common name	Scientific name
RECR	Red Crossbill	<i>Loxia curvirostra</i>
RSTO	Rufous-sided Towhee	<i>Pipilo erythrophthalmus</i>
RTHA	Red-tailed Hawk	<i>Buteo jamaicensis</i>
RUGR	Ruffed Grouse	<i>Bonasa umbellus</i>
RUHU	Rufous Hummingbird	<i>Selasphorus rufus</i>
SACR	Sandhill Crane	<i>Grus canadensis</i>
SOSP	Song Sparrow	<i>Melospiza melodia</i>
SPSA	Spotted Sandpiper	<i>Actitis macularia</i>
SSHA	Sharp-shinned Hawk	<i>Accipiter striatus</i>
STJA	Steller's Jay	<i>Cyanocitta stelleri</i>
SWTH	Swainson's Thrush	<i>Catharus ustulatus</i>
TOWA	Townsend's Warbler	<i>Dendroica townsendi</i>
TRSW	Tree Swallow	<i>Tachycineta bicolor</i>
VASW	Vaux's Swift	<i>Chaetura vauxi</i>
VATH	Varied Thrush	<i>Ixoreus naevius</i>
WAVI	Warbling Vireo	<i>Vireo gilvus</i>
WCSP	White-crowned Sparrow	<i>Zonotrichia leucophrys</i>
WETA	Western Tanager	<i>Piranga ludoviciana</i>
WIFL	Willow Flycatcher	<i>Empidonax traillii</i>
WIWA	Wilson's Warbler	<i>Wilsonia pusilla</i>
WIWR	Winter Wren	<i>Troglodytes troglodytes</i>
WSOW	Western Screech-Owl	<i>Otus kennicottii kennicottii</i>
YEWA	Yellow Warbler	<i>Dendroica petechia</i>
Mammals		
FECO	Cougar	<i>Felis concolor</i>
MAAM	Marten	<i>Martes americana</i>
MUER	Ermine (Short-tailed Weasel)	<i>Mustela erminea</i>
ODHE	Black-tailed Deer	<i>Odocoileus hemionus columbianus</i>
PEMA	Deer Mouse	<i>Peromyscus maniculatus</i>
SOSP	Shrews	<i>Sorex spp.</i>
TAHU	Red Squirrel	<i>Tamiasciurus hudsonicus</i>
URAM	Black Bear	<i>Ursus americanus</i>
Amphibians		
AMGR	Northwestern Salamander	<i>Ambystoma gracile</i>
ANFE	Clouded Salamander	<i>Aneides ferreus</i>
PLVE	Western Red-backed Salamander	<i>Plethodon vehiculum</i>
TAGR	Rough-skinned Newt	<i>Taricha granulosa</i>

APPENDIX 5 Mean number of detections for all birds by habitat type

Habitat	Census 1 mean (SE*)		Census 2 mean (SE)		Census 3 mean (SE)
CWHvm1/ dry / slightly dry	8.33	(0.73)	12.00	(0.74)	11.50 (0.69)
CWHvm1 fresh	7.09	(0.66)	12.14	(0.55)	12.00 (0.70)
CWHvm1/ moist / very moist	10.02	(0.92)	13.25	(1.23)	13.83 (0.98)
CWHvm1/ wet	5.00	(1.00)	11.50	(2.50)	12.00 (1.00)
CWHvh1/ hardwood	13.60	(1.03)	15.00	(1.82)	13.25 (1.03)
CWHvh1/vm1 clearcut	10.33	(1.07)	14.56	(1.63)	15.33 (1.93)
CWHvm2	5.20	(0.39)	9.44	(0.71)	11.56 (1.09)
MHmml	—		6.75	(0.68)	4.75 (0.77)

* SE - standard error

APPENDIX 6 Tukey HSD multiple comparisons matrix of pairwise comparison probabilities of habitat types

Habitat	CWH vm1/dry/ slightly dry	CWHvm1/ fresh	CWH vm1/ moist / very moist	CWH vm1/wet	CWH vh1/ hardwood	CWHvh1/ vm1/ clearcut	CWHvm2	MHmml
CWHvm1/dry/ slightly dry	1.000							
CWHvm1/fresh	0.998	1.000						
CWHvm1/moist/ very moist	0.703	0.930	1.000					
CWHvm1/wet	1.000	1.000	0.997	1.000				
CWHvh1/ hardwood	0.916	0.987	1.000	0.997	1.000			
CWHvh1/ vm1/clearcut	0.202	0.404	0.979	0.921	0.998	1.000		
CWHvm2	0.935	0.616	0.160	0.993	0.482	0.026	1.000	
MHmml	0.000	0.000	0.000	0.002	0.000	0.000	0.000	1.000

